TABLE 4.—*Mean values of atmospheric pressures, temperatures, vapor pressures, and densities, based on sounding balloon observations at Fort Omaha, Nebr.; Indianapolis, Ind.; Huron, S. Dak.; and Avalon, Cal. (English measures)*—Continued.

Year.

Altitude above M. S. L.	Pressures.	Temperatures.	Vapor pressures.	Densities.	
Feet.	*Inches.*	°*F.*	*Inches.*	%	*Lbs./cu. ft.*
26000	10.92	−20.6	0.007	40.9	0.0330
27000	10.46	−24.2	.006	39.5	.0319
28000	10.01	−27.6	.005	38.1	.0307
29000	9.59	−31.0	.004	36.8	.0297
30000	9.20	−34.2	.003	35.5	.0287
Miles.					
6	8.54	−39.6	0.002	33.4	0.0270
7	6.77	−54.2	.001	27.4	.0222
8	5.31	−61.8	.0003	21.9	.0177
9	4.13	−67.0	.0002	17.3	.0140
10	3.20	−69.7	.0002	13.5	.0109
11	2.52	−67.2	0.0002	10.6	0.0085
12	1.98	−62.3	.0002	8.0	.0065
13	1.57	−56.4	.0003	6.4	.0052
14	1.22	−50.1	.0007	4.9	.0040
15	0.95	−41.6	.0014	3.7	.0030
16	0.75	−38.6	0.0008	3.0	0.0025
17	0.63	−36.4	.0007	2.5	.0020
18	0.55	−35.1	.0010	2.1	.0017
19	0.47	−36.8	.0017	1.8	.0015
20	0.40	−44.0	.0002	1.6	.0013

TABLE 5.—*Mean annual atmospheric pressures, temperatures, and densities at various heights above sealevel in England.*

Altitude above M. S. L.	Pressure.	Temperature.	Density.
m.	*mb.*	°*A.*	*kg./cu.m.*
0	1014	282	1.253
1000	900	278	1.128
2000	795	273	1.014
3000	699	268	0.909
4000	615	262	0.818
5000	538	255	0.735
6000	469	248	0.658
7000	407	241	0.589

TABLE 6.—*Mean annual densities, as observed at Mount Weather, Va., in the central and western United States and in England.*

Altitude above M. S. L.	Mount Weather, Va.	Central and western United States.	England.
m.	*kg./cu.m.*	*kg./cu.m.*	*kg./cu.m.*
0	1.226	1.202	1.253
1000	1.113	1.094	1.128
2000	1.002	0.984	1.014
3000	0.903	0.892	0.909
4000	0.816	0.807	0.818
5000	0.731	0.723	0.735
6000	*0.672	0.655	0.658
7000	.....	0.586	0.589

* Based on few observations; figures not regarded as reliable.

THE TURNING OF WINDS WITH ALTITUDE.

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[Dated: Division of Aerological Investigations, Weather Bureau, Feb. 16, 1918.]

Free-air wind conditions, as observed at Mount Weather, Va., have been summarized in the Bulletin of the Mount Weather Observatory (v. 6, pt. 4) and somewhat more briefly in "Meteorology and Aeronautics" by Maj. Wm. R. Blair, recently published by the National Advisory Committee for Aeronautics as Report No. 13. The purpose of the present paper is to present some additional conclusions which may be considered as supplementary to those given in the summaries mentioned; and which are believed to be of considerable interest and value to aviators.

In this summary no free-air observations at altitudes less than 1,500 meters have been used. Those from 1,500 to 2,000 meters have been considered as having reached a height of 2,000 meters. A large number of captive balloon records also have been ignored, as they were made when both surface and upper winds were variable, owing to "flat map" conditions (i. e., no well-developed HIGH or LOW), and no regular or consistent turning of the winds was apparent. Finally, on days when more than one observation was made, only one has been considered, except when the records were obtained under radically different conditions (e. g., before and after the passage of a LOW). With these exceptions, all free-air observations ever made at Mount Weather have been considered, including those in the diurnal series work and in the "International" records in 1913–14. These exceptions should be borne in mind in connection with Table 1, which gives the percentage frequency of winds at the surface from 16 directions.

TABLE 1.—*Percentage frequency of surface winds from 16 directions.*

Direction.	Frequency.
	Per cent.
N.....	1.0
NNE....	0.3
NE.....	0.4
ENE.....	0.6
E.....	0.8
ESE.....	2.8
SE.....	12.6
SSE.....	7.8
S.....	7.8
SSW.....	3.3
SW.....	2.9
WSW.....	3.3
W.....	7.9
WNW...	21.6
NW.....	24.1
NNW....	2.5

The values in this table are slightly different from those in Table 22, v. 6, part 4, Bulletin of the Mount Weather Observatory (repeated in Table 2, p. 44, of Report No. 13, Meteorology and Aeronautics). The latter table is, however, based on observations during 1911–12 only and includes those in which an altitude of less than 1,500 meters was reached. Of the observations in the summer months to a height of less than 1,500 meters, a large proportion were made with a surface wind from north-northeast to east. This wind was in nearly all cases very shallow, and above it there was a layer about 1 kilometer in depth with little, if any, wind. At higher levels clouds, if present, usually indicated a westerly wind. Those observations in winter to less than 1,500 meters in height were usually made in a surface westerly wind which rapidly increased in velocity with altitude, thus beating the kites down. It is probable that these winds would show about the same turning tendencies as those indicated later for the westerly winds.

TABLE 2.—*Mean turning of winds with altitude, when surface winds are of moderate velocity.*

Direction at earth's surface.	Number of observations.	Percentage turning—		
		Clockwise.	Counterclockwise.	Not turning.
		%	%	%
N. to ENE.	31	45	35	20
E. to ESE.	50	76	12	12
SE. to SW.	474	94	2	4
WSW.....	46	76	7	17
W.....	109	51	12	37
WNW.....	298	41	29	30
NW.....	337	29	40	31
NNW.....	34	35	38	27

The following remarks are based on yearly averages. The same tendencies are shown in all the months, but more decidedly in the winter than in the summer half of the year. With surface winds of moderate velocity the turning with altitude for the year is given in Table 2. A detailed study showed that certain groups of surface winds have practically the same turning characteristics—viz, north, north-northeast, northeast, and east-northeast; east and east-southeast; and southeast, south-southeast, south, south-southwest, and southwest. In the first group the tendency to clockwise turning is somewhat greater than that to counterclockwise, about 20 per cent showing no turning. In the second group the clockwise turning is large, about 75 per cent. In the third group it amounts to about 94 per cent. It is greatest, 98 per cent, with south-southeast and least, 89 per cent, with southwest winds. Surface winds from west-southwest, west, west-northwest, northwest and north-northwest could not be grouped and are therefore given individually. The clockwise tendency decreases with surface winds from west-southwest to northwest, being 76 per cent for west-southwest, 51 per cent for west, 41 per cent for west-northwest, and 29 per cent for northwest, the counterclockwise turning being, respectively, 7, 12, 29, and 40 per cent. Winds aloft were the same as at the surface in 17, 37, 30, and 31 per cent of the cases, respectively. Surface north-northwest winds show about an equal tendency to clockwise and counterclockwise turning.

TABLE 3.—*Percentage frequency of a west component at different levels up to 4,000 meters.*

Sea-level altitude.	Number of observations.	West component.
m.		%
* 526	1,378	66
1,000	1,378	79
2,000	1,378	88
3,000	854	94
4,000	397	96

* Surface of ground at Mount Weather, Va.

In Table 3 is shown the percentage frequency of a west component in the winds at various levels. It amounts to 66 per cent of all the observations made at the surface and increases to 96 per cent at 4,000 meters, being higher at all levels in the winter than in the summer months. Little difference is apparent in the value of this component at 3,000 and 4,000 meters. This is also shown by the observations with sounding balloons at Fort Omaha, Nebr., Huron, S. Dak., and Indianapolis, Ind. These observations are not sufficiently numerous or well distributed throughout the year to give definite values, but are of interest in that they show the same general tendencies.

TABLE 4.—*Percentage frequency of north and south components at 3,000 and 4,000 meters under different conditions of wind direction at the surface.*

Direction at earth's surface.	Number of observations.	North component.	South component.	Due west.
At 3,000 meters:		*Per cent.*	*Per cent.*	*Per cent.*
E. to WSW	323	9	66	25
W	82	39	11	50
WNW. to ENE	449	76	6	18
All directions	854	47	29	24
At 4,000 meters:				
E. to WSW	152	11	54	35
W	46	39	13	48
WNW. to ENE	199	73	8	19
All directions	397	45	26	29

Table 4 gives the percentage frequencies of north and south components at 3,000 and 4,000 meters under different conditions of wind direction at the surface. These figures indicate that a southerly component in the surface winds still persists in 66 per cent of all cases at 3,000 meters and in 54 per cent at 4,000 meters; it shifts to northerly in 9 per cent and 11 per cent, respectively. In the other 25 and 35 per cent, respectively, the wind aloft is due west. With surface westerly winds a northerly component prevails in 39 per cent of the cases at 3,000 and 4,000 meters, and a southerly component in about 12 per cent, the remaining 49 per cent continuing west. With surface winds having a northerly component, this component persists in about three-fourths of the cases at 3,000 and 4,000 meters, being 76 and 73 per cent, respectively. At those altitudes there was a southerly component in 6 and 8 per cent of the cases; west winds prevailed in the remaining 18 and 19 per cent. When all observations are considered, it is found that, at 3,000 and 4,000 meters, respectively, due west winds prevail 24 and 29 per cent of the time; a northerly component 47 and 45 per cent, and a southerly component 29 and 26 per cent.

The foregoing discussion and tables are based on average conditions and it is necessary, in predicting wind conditions aloft, to know the pressure distribution prevailing at the time, as charted on daily weather maps. When this distribution is known, fairly reliable forecasts of wind directions can be made by the following rules:

RULES FOR FORECASTING WINDS ALOFT.

(1) With a distant LOW approaching from the southwest, surface winds are easterly and shallow, and above them is a layer about 1 kilometer in depth in which there is little or no wind; above this layer southwesterly winds prevail.

(2) As a LOW passes north of the station, surface winds are successively southeast, south, and southwest, and the turning of wind with altitude is clockwise, the upper winds nearly always being southwest to west.

(3) With a LOW northeast of the station and a HIGH southwest, both surface and upper winds are northwest. As this HIGH approaches and passes south of the station the surface winds are successively west-northwest, west and west-southwest, turning clockwise with altitude to northwest.

(4) With a HIGH east of the station and a LOW approaching from the west or west-northwest, winds are southwest and strong both at the surface and aloft.

(5) With a HIGH north of the station and a LOW approaching from the southwest and passing south of the station, surface winds are north-northeast to east-northeast and there is little turning up to 4,000 meters; the turning at higher levels is counterclockwise to north-northwest and northwest.

(6) With a HIGH northwest and a LOW south of the station, surface winds are north to northeast, turning clockwise with altitude to northeast, and at higher levels counterclockwise back to north-northwest.

(7) With a HIGH on the northwest and a LOW passing northward east of the station, surface winds are successively north, north-northwest, and northwest, turning counterclockwise with altitude to northwest and west-northwest.

(8) In general, the turning of winds with altitude is usually such that they have a westerly component before the 3-km. level is reached.